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COGNITIVE DEVELOPMENT

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COGNITIVE DEVELOPMENT THROUGH AUDITORY PROCESSING

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Abstract

The Glass Bead Game, by Hermann Hesse, is based on a "game" designed to enable cognitive development. The game he refers to is never fully defined- it is based around the concept of the activity. This book provides the foundation of this project- to try and design an activity, or "Game," that helps to further cognition in the human species. Research into the current state of the art in technology relating to cognition, sound, and evolution was studied. Cognitive development, problem solving, and memory were analyzed and utilized to create the Game through more abstract ideas such as emergent behavior and biofeedback. The Game is designed specifically to challenge the brain. The basis of the Game is rooted in the evolutionary history of the human brain.

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Chapter 1: Executive Summary

Throughout evolution, sound has played an integral role in the development of learning in the human species. From the primitive survival stages; learning of threats, adapting, and understanding a sense of space, to establishing a means of communication and understanding within culture to the forming of melody, harmony, and the creation of music.

Sound has been an integral part in our evolution, not only in that of the Homo sapiens but in the brain itself. About two million years ago sound played such a crucial role that it strengthened the evolution of the brain and eventually developed the entire cortex, often referred to as the "crowning achievement of brain evolution."[1]

This achievement was mostly due to the evolution of the "eucynodonts," which were of the first mammals in the world. They displayed advanced hearing capabilities that allowed them to hear predators and prey alike. This meant the eucynodonts were able to localize predators and avoid them and also have keen abilities to finding prey.[2] This led them to getting an abundance of nutrients while developing a strong sense of survival. From this came parental behavior, which meant that young were fed by mothers that had enough nutrients to allow their brains to grow as well, (further developing the cortex). More nutrients in an organism means a bigger brain, and that means a more intelligent being.[3]

This history of the Homo sapiens' brain explains how it has reached the evolutionary stand-point of where it is today. However, humans may have reached this stage as a species that cannot advance further in auditory processing. To advance further would require something greater than our current abilities through some means of a new cognitive challenge. The scope of

[1]Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print. pg 8.
[2]Ibid.
[3]Ibid.

this project is to formalize a theory on how to approach the advancement of human learning through a means of auditory processing. This will be done through some activity that a person may perform, which will be referred to as the "Game" for the rest of this paper. The Game is designed to utilize sounds to challenge our minds, to further the development of the human brain, and to develop human cognition in a new way.

The goal of the Game is to create an activity with goals and challenges; simple minded tasks for beginning players, while concurrently having allowances for a larger scaled, demanding challenge for practiced individuals with highly-flexible memory organization. While inexperienced players are still able to participate and be a part of the challenge, it will take a mastery of the Game to be able to unlock its true potential in developing the human brain.

Creating a system that can evolve itself for the organization of thoughts and the resulting sounds will allow further cognitive development while still providing a challenging experience for the players involved. But how does this kind of memory organization function?

Philosophically, human beings have a supposed set of prioritized values. Ranked from least important to most important, they value perception, memory, thought, and creativity. Interestingly enough, this ranking is identical when asked about the complexity of human skills.[4] It's considerably more complicated for someone to think and create based off of a memory of something perceived than to simply notice or perceive one's surroundings.

[4]Benjamin Kleinmuntz. *Problem Solving: Research, Method and Theory.* New York: Wiley, 1966. Print. 23.

Chapter 2: Literature Review

2.1: Sound, Evolution, and the Brain

Sounds are produced through vibrations in the atmosphere. These vibrations cause chain reactions of air particles vibrating and literally move the sound through its environments. Pressure (sound) waves consist of a frequency and amplitude. These waves translate directly to the pitch and volume received by the human ear. A higher frequency relates to when the pressure fluctuations between compression and rarefaction (higher and lower pressures) happens more quickly, causing a higher pitch. Alternatively, slower fluctuations between compression and rarefaction result in lower pitches. The human ear needs to provide critical functions to appropriately derive brain function.[5]

Figure 1 Diagram of the Inner Ear[6]

The most important of these functions is to be able to capture the surrounding sound waves and direct them into a part of the ear that will allow the signals to be translated and sent to

[5]Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print. Pg 30.
[6]"Human Ear Diagram." *Noisy Jobs Cause a Loss of Hearing? Receive Your Hearing Aids and Compensation.* Web. 22 Feb. 2011. <http://www.noisyjobs.com/human-ear-diagram.html>.

the brain. The outermost part of the ear, the pinna, is designed for this function. It consists of a number of curves and is able to detect a sense of location based off of how sounds are reflected into the ear canal itself. This allows sound localization forward and back of the ear, favoring a more accurate response from sounds in front of the head. Having ears on both sides of the head allows for localization relative to the left and right of the individual. Receiving signals milliseconds sooner to one ear over the other allows this localization to take place. After this process occurs in the ear, the brain analyzes and responds. However, this process took billions of years to develop to where it is now.[7] [8]

The Earth was formed about 4.6 billion years ago, and life began about a billion years afterwards. At first, there were only single-celled organisms, all within the oceans, but eventually they grew to become multi cellular organisms. These organisms now required organization and communication between cells because different cells developed different purposes. Soon after multi-celled organisms were prominent in the world, the neuron, or nerve cell, was formed. This cell was the sensor in the organism that connected all of the inner workings of the organism to the outside world. It was this type of cell that held the sensory systems of the organisms (for example, the stimuli would be sensed by the neuron and the neuron would pass the information to the rest of the cells in order for the organism to respond appropriately).

As these multi-celled organisms developed, their cells began organizing themselves more efficiently. The neuron cells developed near where the organism would eat food, (for a comparison, our brains are near our faces) because that was where most of the sensory information was coming from. Finally, the neuron cells organized themselves into what are

[7]Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print. pg 33.
[8]Ibid. Pg. 8.

called “neural networks.” These networks of cells were better able to communicate and send messages to the rest of the cells that would be able to develop a response for the organism.[9]

Around 570 million years ago, there was a period in the Earth’s history of about 40 million years called the “Cambrian explosion.” This was when the tectonic plates in the Earth were “…moving ten times faster than they do today.”[10] This movement and extreme change in the Earth forced organisms to either adapt to their new habitats or die, causing a need for evolution. Evolution had not moved far from the multi-celled organisms which happily received data in their neural networks and made basic decisions, (such as fight, flight, eat, etc.). But since the planet itself was changing, this pushed living things to have to change and evolve. There was a rapid rise in the diversity of life forms, and this increased the differences in their respective brains.[11] The brains of the organisms had adapted and grown significantly to have a more sophisticated sensory-response system. Though far from the advanced Homo sapien brain, these were still considerably more complex than the original single-celled organisms.

Another important event was the rise from water. Because water does not change much with temperature, the ocean environment was stable and easy for the organisms it inhabited. However, once living things began to crawl from the water, they had to evolve and to adapt in order to deal with the intense changes in weather patterns. Because of this new requirement, the brain had to reassess stimuli around the organism and what the proper responses were. This new assessment required that the brain grow and be able to store that sort of new information.[12]

These were all reptiles that crawled out of the ocean, but soon the reptile family branched out to three different families. The important branch that eventually stems to Homo sapiens was

[9]Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print. pg 3.
[10]Ibid. pg 4.
[11]Ibid. pg 5
[12]Ibid. pg 6

the "synapsids."[13] From the synapsids came an integral member of our evolutionary family, the "cynodonts." These dog-like creatures had developed teeth that were incredibly efficient and took most of the work done by its digestive system. The nutrients from the food they were consuming were now able to get to the rest of the body and the brain much more rapidly. This gave the brain more resources to continue to grow.[14]

With the advantage of being able to get more nutrients out of foods, the cynodonts were soon able to regulate their body temperature through more evolutionary advances. With this new ability to regulate body temperature (much like the human system of being able to sweat and cool our bodies or warm ourselves to a certain degree with hair), cynodonts were no longer stuck to a specific environment or habitat. This meant they could wander and find even more nutrient-filled food. With this advance, parenting behavior followed. They were soon able to feed themselves *and* their young by being able to share their nutrients. Because the young in the species didn't have to find food, they were able to concentrate only on growing. This meant that with every generation, their brains were able to grow and develop further.[15]

Finally, sound played an integral part in the brain's evolution through animals called the "eucynodonts," which possessed superb ears and therefore excellent hearing capabilities. The eucynodonts were able to track prey with surprising accuracy, and mothers were able to feed not only themselves but their young as well. Similarly to the cynodonts, the brains of these animals gained incredible amounts of nutrition and so were able to grow even more and continue

[13]Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print pg 6.
[14]Ibid. pg 7
[15]Ibid. pg 8

developing at what, at the time, seemed like an evolutionary stand-still.[16] The acceleration of cognition due to auditory processing will be discussed later in this paper.

Due to the past billion years, evolution has been able to utilize sound to its advantage in developing present day's human brain.[17] The human ears are one of the most important tools for human brain function. But why is this all relevant?

The synthesis, and ultimately, the use of the Game proposed will theoretically allow humans to train their ears and consequently train their brains to a new level of understanding. Research in the field of human approaches to solving problems is important to have a thorough understanding of in the synthesis of the Game. Without this knowledge, it would be impossible to expect the Game to actually pose an intellectual challenge and would lose sight of its objective.

2.2: The Glass Bead Game

The inspiration for this project, *The Glass Bead Game*[18] by Herman Hesse is a fictitious work based on a future Utopia. The game as described in the story has become the main education system in the world encompassing all the collective knowledge of humanity. Hesse presents an altered history of the world set three hundred years into the future. He imagines a game that connects humanity together and divulges ideas and information. The game is very similar to the Internet, but the story was written in the beginning of the 20th century. Therefore, Hesse could not have predicted such an idea. Throughout the book, Hesse's 'game' is never fully outlined, yet the reader learns ideas about what it actually is. Hesse describes the game in the stages of its creation in the fictional timeline of the story.

[16]Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print.
[17]Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print.
[18] Hesse, Hermann, Richard Winston, and Clara Winston. *The Glass Bead Game: (Magister Ludi)*. New York: Picador USA, 2002. Print.

> "The Game was at first nothing more than a witty method for developing memory and ingenuity among students and musicians....it has long ceased to having anything to do with glass beads."[19]

The idea behind the game was originally meant as a training exercise for students. When it was played with actual glass beads it used them in some way to form musical scores. As it is never really fully described, the game seemed to have been developed as a novelty more than what it was later to become. The game started to become complex:

> "...the Game was so far developed that it was capable of expressing mathematical processes by special symbols and abbreviations. The players, mutually elaborating these processes, threw these abstract formulas at one another, displaying the sequences and possibilities of their science. This mathematical and astronomical game of formulas required great attentiveness, keenness, and concentration."[20]

The game became a mathematical activity based on formulas and collective knowledge. The game required a lot out of its users. In the story, education in the world completely changed. Professors became less desired and all higher education was developed through the game. Children went to school to train for the game, and took an entrance exam once they were around fifteen. The scale of the game engulfed the entire fictitious world described the in the story:

> "...the Glass Bead Game, in spite of its popularity among scholars, had remained a purely private form of exercise. It could be played alone, by pairs, or by many, although unusually brilliant, well-composed, and successful Games were sometimes written down and circulated from city to city and country to country for admiration or criticism."[21]

The education system of the world relied on this game. It had become the event, the greatest thing the world had in common. The book's vagueness about the game leaves the imagination open about what type of activity could bring all the knowledge of the world

[19]Hesse, Hermann, Richard Winston, and Clara Winston. *The Glass Bead Game: (Magister Ludi)*. New York: Picador USA, 2002. Print. Pg. 31
[20]Hesse, Hermann, Richard Winston, and Clara Winston. *The Glass Bead Game: (Magister Ludi)*. New York: Picador USA, 2002. Print. Pg. 31 to 33
[21]Ibid. Pg. 39

together. In the beginning of the book, Hesse describes the game as having more to do with music. Eventually it turned into the mathematical challenge described above. The goal of this project is to apply this basis to some literal meaning and form an idea of how this game could realistically exist.

> "The mathematicians brought the Game to a high degree of flexibility and capacity for sublimation, so that it began to acquire something approaching a consciousness of itself and its possibilities. This process paralleled the general evolution of cultural consciousness of itself and its possibilities."[22]

Within the development of the game, mathematicians were the ones who made the game serve a purpose globally. Hesse was referring to the game as continuously evolving and feeding information back into itself. "Capacity for sublimation" refers to the game displacing information in a more useful way. It was as though the game became self-aware and mirrored humanity's evolution. "The Game was not mere practice and mere recreation; it became a form of concentrated self-awareness for intellectuals."[23] The game became more than just an assortment of equations and ideas. Intellectuals could now focus on subjects easier and more importantly, were more connected with each other.

Hesse's story provides the introduction to this project. Although the story is science fiction, something akin to this could be possible. The story provides a good basis and idea behind the Game developed by this project.

2.3: Problem Solving

Dr. Margaret Matlin is a distinguished figure in the world of cognitive psychology. One of Matlin's published works, *Cognition*, states that "Understanding the problem is focusing on

[22]Hesse, Hermann, Richard Winston, and Clara Winston. *The Glass Bead Game: (Magister Ludi)*. New York: Picador USA, 2002. Print. Pg. 32
[23]Ibid. Pg. 33

the appropriate part of the problem."[24] This phrase has been a main focus during the synthesis of the Game. The players need to have an understanding of what needs to be solved, and the appropriate methodology to actually solve what is presented to them to be successful. The Game is designed to be complicated, so without being able to focus on the appropriate part of the problem, players find themselves lost and unable to adequately concentrate on playing through to solve what they are given. Similar to that of a soldier at war, to the untrained person a sense of being overwhelmed would be expected in a combat situation. However, a trained individual is able to focus on appropriate, rational decisions and thus would have a much more suitable reaction to their surroundings.[25] [26]

Problems, regardless of their nature, all consist of three parts: the original state, the goal state, and the rules. An example to help clarify the stages would be if a person was stuck on the side of the road with a flat tire. The definition of the original state is the initial phase of the problem. So, the person has the realization that they have a flat tire and pull to the side of the road. The goal state is the final stage which is the solution to the original problem. Obviously, the goal would be to either, try to receive help or to fix the flat tire themselves. The last parts of the problem, the rules, are the obstacles that help define the problem. Some applicable rules to this example could be that there is a spare tire and jack in the trunk or that you're uncomfortable in your surroundings. These three parts are applicable to every problem that people encounter in their daily lives. When looking into defining a problem this structure should always be taken into account.

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[24]Matlin, Margaret W. *Cognition*. Fort Worth: Harcourt Brace, 1994. Print. Pg. 33

[25]Medin, Douglas L., Brian H. Ross, and Arthur B. Markman. *Cognitive Psychology*. Hoboken, NJ: John Wiley & Sons, 2005. Print.

[26]Coren, Stanley, Lawrence M. Ward, and James T. Enns. *Sensation and Perception*. Hoboken, NJ: J. Wiley & Sons, 2004. Print.

In the scope of this project, the aim is to have an average person (the original state) develop advanced cognitive skill through playing the Game (the goal state). The structure for the parts of a problem exists in this project. Beyond the basic structure of problems, exist well-defined factors that will influence problem solving. A number of factors include expertise, memory, knowledge base, speed and efficiency, representation, appreciation of structural similarity, elaborating on initial state, and metacognitive skills.

Expertise and memory are the most prominent of these factors. Expertise in a certain field would help if the particular situation arises. In the example of the person getting a flat tire, if someone was mechanically inclined, they would change the tire themselves using the tools in the car and move along. However, a novice may attempt to change the tire, but will likely call for help. Matlin describes the difference in expertise, "...novices typically focus on salient surface features, whereas experts frequently emphasize the structural features that target the problem and the source problem share."[27] This is what she refers to as the analogy approach.[28] A novice would not look at the structure of a problem if they are not too familiar with it. Memory comes out of expertise as experts are better at recalling information that pertains to their area of work.

Remembering relevant information is an important part of problem solving. Human memory is more complicated than that however, as shown in the section above. For example, in chess human memory shows a complication. Imagine a chessboard with all of the pieces in their appropriate opening positions. As a game between a novice and expert progresses, pieces are moved on both sides. A number of turns in, players are told to close their eyes and the board and pieces are removed. They open their eyes and are told to place each piece with their relative locations onto a blank chessboard. When asked to do this, the novice players are found to have

[27] Matlin, Margaret W. *Cognition*. Fort Worth: Harcourt Brace, 1994. Print. Pg. 33.
[28] Ibid.

an extremely low retention rate, while the experts were found to almost always have near-perfect retention. This is due to their ability to focus on the appropriate part of the problem.[29]

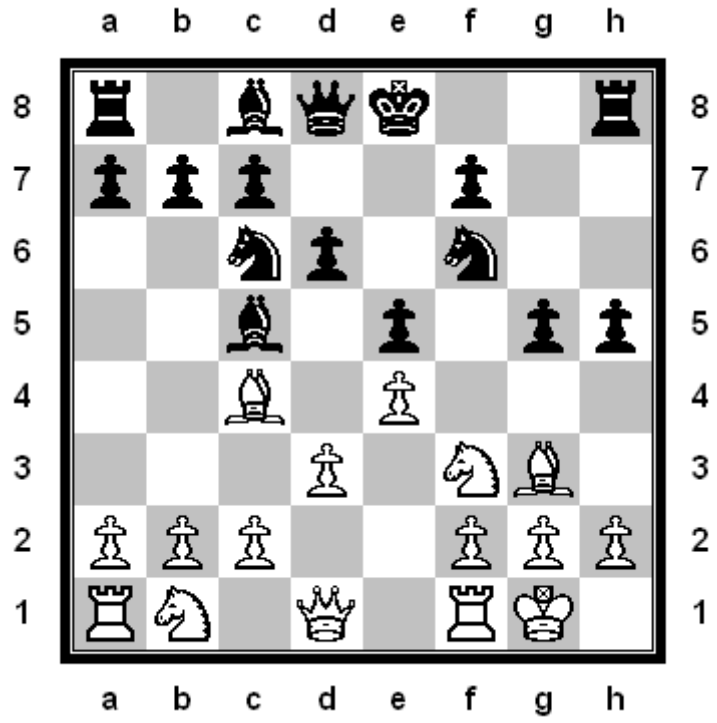

Figure 2 Mid-game Chessboard[30]

The complication is that specific retention is only applicable in the sense of the game and the rules. If all of the pieces were randomly positioned about the board, both the novice and expert alike were found to have difficulty in retention. It becomes a memory game at that point, and the expert loses the advantage in the developing strategy during an actual chess game. Since the pieces cannot move or overtake, it becomes a memory problem. This causes memory to become a crucial component to problem solving, regardless of the player expertise. Applying this concept to the Game, the complication is difficult to avoid.

[29] Matlin, Margaret W. *Cognition*. Fort Worth: Harcourt Brace, 1994. Print. Pg. 34
[30] "CSS3 Chess Board | Design in Development." *Design in Development | Creating Elegant Designs with Ones and Zeros*. Web. 28 Feb. 2011. <http://designindevelopment.com/css/css3-chess-board/>.

Knowledge base, representation, and an appreciation of structural similarity are also important in distinguishing novices and experts. Knowledge base goes back to expertise; someone in a particular field of study would have more knowledge around that field of study. A mathematician would be better at solving math problems, and a physicist would be better at physical problems. Representation is how the problem solver chooses to view the problem. A novice would represent the problem in a naïve way, usually based on real world objects. An expert would be more inclined to construct representations on abstract ideas. Many times an expert will identify a problem with a problem that has already been solved. They see similarities between problems that allow for the problem to then be solved easier.[31]

The last three factors, elaborating on initial state, speed and efficiency and metacognitive skills are equally important in problem solving. Elaborating on the initial state is simply that experts will be more apt to thinking about the initial state of a problem, while a novice will not focus on it. This is usually called the "given" parts of a problem. Identifying the givens is usually the best way to start a problem. Speed and efficiency allow for experts to have fast, effective strategies. Experts' operations will be more automatic and have a quick trigger response. They will have a much more efficient problem solving strategy. They sometimes will employ "parallel processing" rather than "serial processing." This difference is best identified when looking at people solving anagrams. An expert will be able to design multiple solutions simultaneously, whereas a novice will look at only one solution at a time. This would allow the expert to solve the problem much quicker than the novice.[32]

Metacognitive skills are very important at every stage of problem solving. "Metacognition refers to learners' automatic awareness of their own knowledge and their ability

[31] Matlin, Margaret W. *Cognition*. Fort Worth: Harcourt Brace, 1994. Print. Pg. 36
[32] Ibid. Pg. 37

to understand, control, and manipulate their own cognitive processes."[33] A person with great metacognitive skills would be better at judging the problem difficulty, awareness of making an error, and allocation of time. The idea is that subconsciously an expert would have a good "gut reaction" to any problem and somewhat automatically be able to tell the difficulty, errors they may make or have made, and use their time appropriately.[34]

2.4: Memory

The idea of heuristics states that, "Learning produces memory."[35] While some problems are easily solved in one or two logical steps, there are times when they can't simply be solved without some determined sequence. These types of problems require longer time periods to solve as they deepen in complexity, along with an ability to group thoughts and a strong memory to be completed successfully. There is a definite degree of difficulty with solving these types of problems, as there is a direct cost on the brain to formulate and retain plans and groupings of information.[36]

Memory falls into three categories: sensory, short term, and long term. Sensory memory is the result of perception, and in most cases it dissolves immediately. In other words, a person watching a movie may see that an insignificant character is wearing a yellow tie, but will not remember this unimportant detail. Or, "echoic memory" is an example of a sensory memory. An example of echoic memory is when a student is not paying attention but can still repeat the last few words the teacher said.[37]

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[33] "Metacognitive Skills." Metacognitive Skills. Web. 01 Jan. 2011. <http://education.calumet.purdue.edu/vockell/edPsybook/Edpsy7/edpsy7_meta.htm>.
[34] Matlin, Margaret W. *Cognition*. Fort Worth: Harcourt Brace, 1994. Print. Pg. 37
[35]Groner, Rudolf, Marina Groner, and Walter F. Bischof. *Methods of Heuristics*. Hillsdale, NJ: L. Erlbaum Associates, 1983. Print.
[36]"THE BRAIN FROM TOP TO BOTTOM." *LE CERVEAU À TOUS LES NIVEAUX!* Web. 11 Oct. 2010. <http://thebrain.mcgill.ca/flash/i/i_07/i_07_cr/i_07_cr_tra/i_07_cr_tra.html>.
[37]Ibid.

Short term memory is when someone may remember something for up to a minute, and be able to use that piece of information within that time frame. The average person can remember 7 items for a single minute, (which is why phone numbers are only 7 digits long). After the minute, however, the 7 items will be erased from that person's mind.[38]

Long term memory is what stays with a person because facts and ideas are consolidated into three steps; encoding, storage, and retrieval. Encoding is when a person puts a meaning behind an item, such as how a pair of pants has two legs, has three holes, and is generally worn on the bottom of a person's body each day. If one cannot think of the word "pants," the idea of two legs may be the key to being able to remember, or another piece of information (that is why when someone cannot think of a word they often begin to describe the item so that they can remember). Also, this is helpful in learning, since when one must memorize a list of items one can make a pattern, or "encode" them. Acronyms are examples of shortening longer lists into short precise lists to better be able to remember.[39]

The second step to adding something to long term memory is storage. Storage is exactly as one would assume- it is streaming the information that has been encoded into the brain. This usually occurs best during sleep and studying, (also called reviewing). This is why students who review and get plenty of sleep before an exam tend to do better than those who "pull all-nighters" to review and do not sleep.[40]

The final step to long term memory is retrieval, which is the whole point to having memory. Retrieval is recalling information using the coding that the brain attributed to that particular piece of information. This step may or may not be voluntary, but when the information

[38]"THE BRAIN FROM TOP TO BOTTOM." *LE CERVEAU À TOUS LES NIVEAUX!* Web. 11 Oct. 2010. <http://thebrain.mcgill.ca/flash/i/i_07/i_07_cr/i_07_cr_tra/i_07_cr_tra.html>.
[39]Ibid.
[40]Ibid.

has more structure and is more elaborately coded, (for example, when one studies a particular piece of information longer and uses more coding to describe it), it is easier to retrieve and recall when needed.[41]

As a note, working memory is a sub-set of long term memory. When one retrieves a piece of information using coding, it is put into the "working memory" which is literally the memory that is being currently used.

Aging brains suffer memory loss because: "...neural connections, which receive process and transmit information, can weaken with disuse or age."[42] The brain is a muscle, and like any other muscle the brain needs to be exercised. Dr. Kathleen Taylor (a professor at St. Mayr's College of California) stated that: "The brain is plastic and continues to change, not in getting bigger but allowing for greater complexity and deeper understanding… As adults we may not always learn quite as fast, be we are set up for this next developmental step."[43] Dr. Taylor has been studying ways to teach adults effectively, and so she realized that rather than being able to learn facts as quickly and easily as younger brains, adults and aging brains are developed in a way so that concepts and overall understanding of facts and how they connect are learned easily.

> "Educators say that, for adults, one way to nudge neurons in the right direction is to challenge the very assumptions they have worked so hard to accumulate while young. With a brain already full of well-connected pathways, adult learners should 'jiggle their synapses a bit' by confronting thoughts that are contrary to their own, says Dr. Taylor, who is 66."[44]

In other words, adults should attempt to think contrary thoughts to what they have been brought up with, to think "outside the box." This will strengthen and

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[41]"THE BRAIN FROM TOP TO BOTTOM." *LE CERVEAU À TOUS LES NIVEAUX!* Web. 11 Oct. 2010. <http://thebrain.mcgill.ca/flash/i/i_07/i_07_cr/i_07_cr_tra/i_07_cr_tra.html>.

[42] Strauch, Barbara. "How to Train the Aging Brain." *The New York Times*. 29 Dec. 2009. Web. 16 Feb. 2011. <http://www.nytimes.com/2010/01/03/education/edlife/03adult-t.html?_r=2>.

[43]Ibid.

[44]Ibid.

even create new pathways in the brain. The neural connections will be stronger and so adult memory and brain capacity will strengthen even with age. That is the objective of the Game- to strengthen and keep the player thinking in new, original, and imaginative ways.

2.5: Emergent Behavior

"Emergent behavior is the phenomenon of how small, simple rules can expand into very sophisticated and interesting high-level behavior."[45] [46] This quote describes emergent behavior perfectly; emergent behavior is when an unplanned by-product occurs because of a planned event. This means that emergence occurs without any effort of any person. "Sometimes a system with many simple components will exhibit a behavior of the whole that seems more organized than the behavior of the individual parts."[47] The definition of emergence is that it is unpredictable and it produces a higher level product that was originally planned.[48]

This topic will be discussed relative to the Game later on in the paper.

2.6: Human Control Theory

Human beings acting as "adaptive controllers" are a large part of developing the Game. An adaptive controller is something that can change its behavior, either continuously or abruptly, according to the changes in its environment in order to "stay the course," or, in other words, to keep on the projected path because the parameters are "slowly time-varying or uncertain."[49]

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[45] Johnson, Steven. *Emergence: The Connected Lives of Ants, Brains, Cities, and Software*. New York: Scribner, 2001. Print.

[46] "Emergent Behavior." *Clarkwood Software*. Web. 25 Oct. 2010. <http://www.clarkwood.com/articles/emergent_behavior/>

[47] Hillis, Danny. "Intelligence as an Emergent Behavior Or, The Songs of Eden - The Long Now."*Front Page - The Long Now*. 16 Feb. 2010. Web. 21 Feb. 2011. <http://longnow.org/essays/intelligence-emergent-behavior-or-songs-eden/>.

[48] Hillis, Danny. "Intelligence as an Emergent Behavior Or, The Songs of Eden - The Long Now."*Front Page - The Long Now*. 16 Feb. 2010. Web. 21 Feb. 2011. <http://longnow.org/essays/intelligence-emergent-behavior-or-songs-eden/>.

[49] Jagacinski, Richard J., and John Flach. Control Theory for Humans: Quantitative Approaches to Modeling Performance. Mahwah, NJ: L. Erlbaum Associates, 2003. Print.

The question asked in the book *Control Theory for Humans: Quantitative Approaches to Modeling Performance*[50] is whether people themselves can be adaptive controllers. In order to be an adaptive controller, the control system would have to be able to change from position control to velocity control, and finally to acceleration control and back. This means that the control system would have to be able to change according to its surroundings; rather than being stationary at one point it would have to be able to move. Similarly, rather than moving at a constant rate, the control system would have to be able to move in different directions and be able to speed up or slow down. Relatively, a human adaptive controller would have to be able to do the same. For example, if a person is playing a video game that speeds up and slows down, that person would have to be able to change their behavior in order to keep up with the game. However, this analogy does not completely describe the role of an adaptive controller, since the controller is, of course, in "control."[51]

Another problem for a person to be an adaptive controller are the two possibilities when it comes to responding to a stimuli (also known as inputs). It depends on if the input signals determine the person's behavior, or if the person is able to respond with any behavior to the signals. If the input only produces a single response from the human performer, then obviously they are not capable of other forms of adaptive control. In the opposite case, (or the latter description above), the person would be perfectly capable of being the adaptive controller, (since they would be able to respond differently to the same inputs, or to change).[52]

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[50] Jagacinski, Richard J., and John Flach. Control Theory for Humans: Quantitative Approaches to Modeling Performance. Mahwah, NJ: L. Erlbaum Associates, 2003. Print.
[51] Jagacinski, Richard J., and John Flach. *Control Theory for Humans: Quantitative Approaches to Modeling Performance*. Mahwah, NJ: L. Erlbaum Associates, 2003. Print.
[52] Ibid.

There is another condition that would keep a person from being an effective adaptive controller, and that is if the feedback is immediate or not. Just as in how punishment works against a person or positive/negative feedback works, it must be immediate otherwise the punishment, positive/negative feedback will be worthless.[53]

2.7: Games Meant for Brain Development

There have many games that stimulate the development of younger brains, mainly infants to young adults. These focus on the same topics that they focus on in school and are meant as a learning aid. Recently there have been numerous games directed at adults and senior citizens that focus on brain stimulation. They have trends that focus on word, mathematics, factual, and puzzle games and have had some interesting results.

One game in particular is Brain Age[54], which is based on the research of Japanese neuroscientist, Ryuta Kawashima. He focused his research on the activity of the brain's responses during specific, goal-oriented activities, and designed a game to focus on targeting those responses to stimulate brain development. In a CNN report about keeping your mind and body healthy they state that, "An active brain produces new connections between nerve cells that allow cells to communicate with one another. This helps your brain store and retrieve information more easily, no matter what your age."[55] The report includes activities that an older brain should practice regularly and many of them are included in Brain Age.

[53]Jagacinski, Richard J., and John Flach. *Control Theory for Humans: Quantitative Approaches to Modeling Performance*. Mahwah, NJ: L. Erlbaum Associates, 2003. Print.
[54] "Brain Age: Train Your Brain in Minutes a Day." *CVGames.com*. Web. 22 Feb. 2011. <http://www.cvgames.com/?p=1931>.
[55]"How to Keep Your Mind Sharp: Preventive Action." *CNN.com - Breaking News, U.S., World, Weather, Entertainment & Video News*. Web. 28 Feb. 2011. <http://www.cnn.com/HEALTH/library/HA/00001.html>

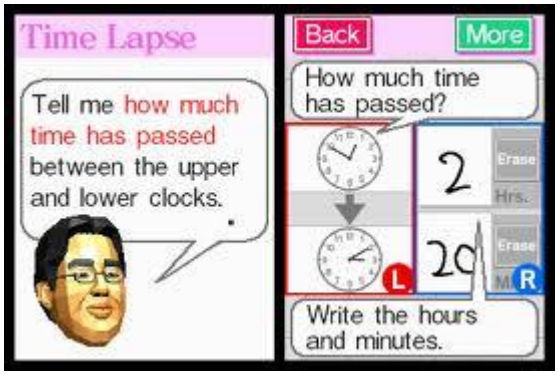

Figure 3 Brain Age[56]

In an interview, Dr. Kawashima explains that "Brain Age" is a term used in the game to rate the age your brain actually is:

> "The mental age is calculated from expected average cognitive functions of specific age of people. For example, if you perform a cohort study of memory function of healthy people, you would find age-related decline of memory function due to normal aging. Also, you could calculate regression line between age and scores of memory function tests that enable you to calculate expected average memory function of specific age of subjects. Then when you refer that regression data, you could know your memory function, that is, your test score, is the same level as average people of some specific age. This is the mental age calculated from memory tests. We combined results of several cognitive tests to calculate the mental age in DS games."[57]

The game described above is a visual and mathematical cognition developing system. Memory has a natural tendency to decline throughout life. Dr. Kawashima has tracked this regression data and transformed it into a brain rating system in comparison to everyone out. The "mental age" aspect of Brain Age could be used in this project. In the *Glass Bead Game*, Hesse states that the beginning of the game began in music then incorporated mathematics. This game could be a stepping stone in both the progression of Hesse's story as well as cognitive development.

[56] "Brain Age: Train Your Brain in Minutes a Day." *CVGames.com*. Web. 22 Feb. 2011. <http://www.cvgames.com/?p=1931>.

[57] Brian Ashcraft. "Interview With Brain Age Professor." *Kotaku*. April 11, 2006. Retrieved December 8, 2010. <http://kotaku.com/166452/interview-with-brain-age-professor>

2.7 Cognition Acceleration due to Auditory Processing

It has been long-proven that auditory processing can accelerate cognition.[58] In an experiment conducted by three psychologists, Douglas S. Goodin, Kenneth C. Squires, and Arnold Starr, it was found that in patients suffering from dementia sound was still "recognizable." In other words, when exposed to certain pitches, the patients were able to remember them and keep them in their long-term memory despite their condition.[59]

There has also been research done with children about the connections between dyslexia, reading learning disabilities, and auditory processing. It turns out that children who suffered with auditory processing and who had problems with reading in the earliest stages of schooling (kindergarten and first grade) were often diagnosed with dyslexia later on (third grade).[60] This shows that auditory processing is an incredibly important portion to the development and continued development of cognition.

Without being able to process auditory stimuli, a large portion of the brain (both of the temporal lobes) would go unused. This means that the "…home to Broca's and Wernicke's areas…"[61] is under-developed. Broca's and Wernicke's areas are both critical points in the brain that are devoted to language, (both speaking and understanding). In other words if auditory processing did not exist, not only would the Homo sapiens' ancestors lack any sort of way to hear prey or predators, but they would be entirely incapable of communication through language.

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[58] Goodin, Douglas S., Kenneth C. Squires, and Arnold Starr. *Long Latency Event-related Components of the Auditory Evoked Potential in Dementia*. Dec. 1978. Web. 17 Jan. 2011. <http://www.ncbi.nlm.nih.gov/pubmed/737523>.

[59] Goodin, Douglas S., Kenneth C. Squires, and Arnold Starr. *Long Latency Event-related Components of the Auditory Evoked Potential in Dementia*. Dec. 1978. Web. 17 Jan. 2011. <http://www.ncbi.nlm.nih.gov/pubmed/737523>.

[60] "More Research on the Importance of Auditory Processing Abilities for Reading « Thoughts from Be Amazing Learning." *Thoughts from Be Amazing Learning*. Web. 011 Nov. 2010. <http://beamazinglearning.wordpress.com/2011/02/07/more-research-on-the-importance-of-auditory-processing-abilities-for-reading/>.

[61] Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print. Pg 52.

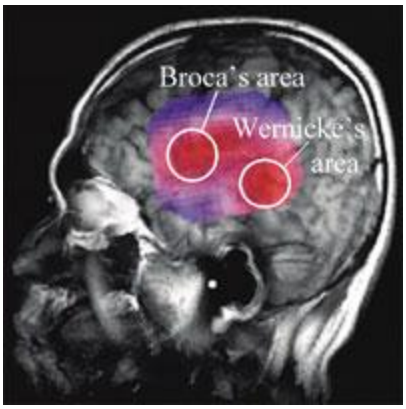

Figure 4 The Brain at Work[62]

Figure four is a picture of an MRI while the patient was subjected to listening and understanding a conversation. Without this capability of auditory processing, one would not be able to understand any language nor would they be able to utilize this large portion of their brain and thus the epitome of their cognition. That is why auditory processing is so imperative to the development of cognition and the continued acceleration of cognition in Homo sapiens.[63] [64] [65]

[62] Spinney, By Laura. "Optical Topography and the Color of Blood - The Scientist - Magazine of the Life Sciences." *The Scientist : Home : Tuesday*. Web. 25 Feb. 2011. <http://f1000scientist.com/article/display/15220/>.
[63] Spinney, By Laura. "Optical Topography and the Color of Blood - The Scientist - Magazine of the Life Sciences." *The Scientist : Home : Tuesday*. Web. 25 Feb. 2011. <http://f1000scientist.com/article/display/15220/>.
[64] Gibb, Barry J. *The Rough Guide to the Brain*. London: Rough Guides, 2007. Print.
[65] Goodin, Douglas S., Kenneth C. Squires, and Arnold Starr. *Long Latency Event-related Components of the Auditory Evoked Potential in Dementia*. Dec. 1978. Web. 17 Jan. 2011. <http://www.ncbi.nlm.nih.gov/pubmed/737523>.

Chapter 3: Game Design

3.1: Design Considerations

The following is a compilation of structural game design, general game strategy, and a further reinforced proof in relation to the proposed structure of the Game. Hesse's story provides little structure to the creation of his game. In order to provide the foundation for the Game, the project will look into the current state-of-the-art that has not been provided in *The Glass Bead Game*. One important consideration to take in the design of this activity is the idea of an incorrect play or movement. It's crucial to understand the depth of restrictions given by the rules to realize the number of possible reasonable moves, ideal moves, or experimental moves. Without there being a clear indication of fault, (immediate, clear/ subtle, slow) the player will become lost without some sense of direction.

The objective of the Game could be thought of as a puzzle; at the beginning, the player (or players) may hear the piece in its entirety, but it then falls to pieces and the player(s) must put them back together. Since the Game must be able to be played by novice and expert alike, the organization may vary accordingly. For example, the novice would be allowed to organize in the most obvious and trivial relationships possible, while the expert would see the intricacies in smaller and less defined relationships.[66] The objective is to put the relationships together, working up from the small sounds being emitted to the full piece once more, utilizing cognition and memory alike.

Since the Game challenges and develops the mind in so many ways, one may wonder how long the Game may take to play or the activity to perform. The length could be miniscule, or potentially endless- it could be thought closely to the raising of children, or how long the seasons

[66]Margaret Matlin. *Cognition*. Fort Worth: Harcourt Brace, 1994. Print.

take to change and how they may impact oneself. Raising a single child takes years and years- and then a parent is usually around for a significant portion of the child's life so that they may fall back upon their parents when in need. In other words, the Game may take a mere eighteen years, as some parents raise their children and send them off into the world- but for a more advanced mind, it may take longer, as some parents raise their children and then help them through college, allow them to live at home, and continue to take care of them well beyond eighteen years of age.

The Game's setting is also an important aspect, as it may target different types of people. People from very different backgrounds would simultaneously be playing this one Game with unforeseen results. The Game could also be played in a large or small setting, with as many or as few players as the people prefer. It is also necessary to look at the Game being able to be played in an outdoor setting rather than strictly indoors. It is possible for this activity to take place in an open field, where sound would travel differently. This would bring a new level to the Game as the distance from the origin of the sound to the players could be drastically different.

While the Game has an overlying trend to be open ended, allowing too much freedom complicates the Game and then it will fail for our purposes. If the Game is left with the sense of having nowhere to go, the player is left idly playing the Game with limited creative function, and more importantly, limited brain function. In a situation where an assignment is given without well-defined boundaries, players are found to stay within their natural comfort zone to supply a suitable, appropriate response to the assignment. In the sense of the proposed activity, an open ended rule set would likely leave players to creating cliché, modern sounds, defeating the purpose of the activity. As such, the rules are designed to lead players away from the cliché, modern sound, and challenge them on a deeper level of understanding and creativity.

While certain moves and strategies are simply incorrect, there should also be a well-defined set of variation allowed in the activity. Similarly to chess, there are a number of methods to overcome the challenge presented in the Game. Methods may be based on an able perception of the entirety of the Game's layout, strategy, personal tendencies, experience or a multitude of other possible means of reasoning. These methods are used simultaneously to achieve a simple goal; grouping and the organization of sound.

Ideally, the focus of the activity should be on its ability to induce learning and the user's ability to establish a solution to the challenges presented in the Game. However, creating a game solely so complicated as to truly challenge the human brain on levels previously never reached would become literally, too complicated for the users, and would lead to a sense of being overwhelmed. This is a very important consideration to take into account. A "bare bones" approach should be accessible for people who do not wish to be challenged to the fullest extents of the Game's intentions. The bare bones approach allows for users to become comfortable with a limited set of controls and variations to help familiarize them with the challenges and a simplified sense of what can be done with the interface. While this approach does not challenge the brain to the extent of our intentions, it's important to create a level of interest in the Game and to train users appropriately.

> "Play is a voluntary activity or occupation executed within certain fixed limits of time and place, according to rules freely accepted but absolutely binding, having its aim in itself and accompanied by a feeling of tension, joy, and the consciousness that it is 'different' from 'ordinary life'."[67] – Johan Huizinga

In order for the proposed activity to be successful, taking a look at modern game theory and structure is an important consideration. While the activity may be flawless in the sense of

[67] Huizinga, Johan. *Homo Ludens*. London: Routledge, 2000. Print. Pg. 28

auditory cognition, if it is not entertaining for its users, it will not be successfully implemented into the real world. Replay and interest value decrease if it is not entertaining, so having a game solely designed to enhance auditory cognition is impractical. The entertainment value and the value of the challenges themselves are a basis for which motivation to play the Game has its core, leaving auditory cognition as a byproduct of taking part in the activity.

Through this method, the activity will interest the mainstream medium of enthusiasts who are able to play variations of the Game depending on personal interest. The enthusiast will be completely immersed into the control and sway of the activity with given, well-defined bounds, making them the key proponent in the Game. The interface should be easily understood to its users while at the same time allowing innumerable functions and limitless possibilities if decided on by the enthusiast to use. This interface design allows the users to decide how challenging (and ultimately, rewarding) the activity presented will be to the user. This also allows users to "build up" a methodology to solving the challenges in the Game such that as challenges increase in difficulty, the user has already established an increasing set of tools to overcome the obstacles presented.

Another thought of how to design the Game is akin to that of a puzzle. "A million tiny pieces of information can become one large picture; this high-level perspective can become much more intuitive to us humans…"[68]

This quote is exactly how the Game could work- at the beginning the player could be presented with the final piece with all of its respective sounds intact and in the proper place. But then everything would shatter, and spouts of information will begin to emit from the speakers so the person could then piece the sounds back together.

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[68]"Emergent Behavior." *Clarkwood Software*. Web. 25 Oct. 2010. <http://www.clarkwood.com/articles/emergent_behavior/>

The Game is all about being able to remember each piece and being able to organize, or reorganize, the piece back together in its entirety, or even in another, more genius version of the original piece. Be it sound or a musical tune, the Game will create a puzzle that the player must try to figure through and solve using their own logic and creation. Simply put, this is connecting the left and right brain- the player must use their logic to put pieces together and to take them apart, and in order to organize them in the end. However it also requires a certain amount of creativity, in that the player must be able to *create* the end piece, and *create* the sounds within it using the sounds given.

3.2: Strategic Considerations

A dark room is set so that when the player walks in they are surrounded by a multitude of speakers all within a certain distance and at a certain height (ear-height of the player at that time). There is a place in the center of the room where that player controls everything. The sound can be controlled simply with the movement of the player's body, or with the swipe of their hand. Sounds are emitted from the speakers and it is the player's job to organize and create more sound from that which is supplied to them. They do so by moving the sounds from speaker to speaker, being able to mesh sounds, or separate them.

The Game never really ends, sort of how a piano player never is completely done learning how to play. There are the basics that a player may master, of course, such as learning which keys are associated with what notes, or in the context of the Game where each speaker is and learning how to master the movement of sound. There is never an ending to the Game. After a few hours a first-time player may master the movement of their hands and therefore how the sounds may move from one speaker to another. However, as soon as that is done they must then master how to follow each sound, how to memorize where it is and how to reorganize them all

together again. And once that is learned, the speakers may move, or speakers may be added. The Game never stays at one level- it moves along just as the player masters another piece of the puzzle.

The example above describes the most basic type of game-play. The philosopher Schopenhauer said, "Every man takes the limits of his own field of vision for the limits of the world."[69] The Game in its entirety is still present in this most basic form of the Game, though the beginning player might not realize the outskirts of what is currently around them.

Of course, the Game in its entirety does not have to be set up in this way. Quite frankly, the Game may be set up in an infinite amount of ways, as long as it is conducive to cognitive development. There must be a place available where the sound can emit from (that being the main portion of the Game), and that has everything to do with speakers, where the speakers are getting their source of power, and how the controller may be "hooked up." Or at least, that's what a beginner to the Game might believe. It would be entirely possible to have the Game more portable, and able to be handled almost anywhere. For example, if the player were in a field where there were no speakers hooked up perhaps the controller would be able to emit sounds and the person could play a different sort of memorization rather than organization game. The controller (whatever it may be: a cell phone, a chip in one's jacket, a chip in one's shoe) would emit several sounds, and the person would have to be able to order them from first to last, last to first, or given a random order of numbers organize the sounds in that order (as supplied by the Game).

[69] DiChristina, Mariette. "Limits of Perception: Scientific American." *Science News, Articles and Information | Scientific American*. Web. 23 Feb. 2011. <http://www.scientificamerican.com/article.cfm?id=limits-of-perception>.

Another consideration is having people be able to recognize the Game. If it gets too abstract, it would be impossible to even realize that you might be playing and it would be nearly impossible for a person to play (after all, how would you play a game if you didn't know what was going on?). For example, if the playing field were to be within a train station for people to have an activity while waiting for their train. They would first have to be able to realize that the Game was being played to actively play a part in it. This sort of implementation would be meant more for general cognition work; in other words, not for the health of a particular patient's brain but for the general public instead. There might be a sign upon entering, or simply a hint in the sounds that are emitted. The speakers might emit a certain pattern of sound that a person would have to recognize before being able to take part in the Game. Another possibility could be if one person were to be told that the Game was available at the time and the station was already hosting it. They would then have primary control over the sounds, and others would eventually realize that the primary player was controlling the sounds in the station, and join in, trying to attain a sense of organization.

Another player would be able to join if they had recognized the sounds around themselves. The sounds may seem oddly organized in only a way that the Game might reflect- for example, if a small high pitched noise were being emitted for four beats at a time. Or they were able to recognize that certain sounds that were once separated were then connected and meshed together to create a new original sound.

Of course, many levels could be played. The beginning of the Game would be a simple version, but as people came and left the station it would evolve and adapt to whatever was required of it from the players present. For example, if there were a beginner and an expert both playing simultaneously, in order to keep the beginner up-to-speed with the Game and not left

behind the expert would be given more sounds to organize while the beginner would not be expected to even recognize those sounds as being part of the Game. This way the expert may place these sounds in whichever organizational pattern he wished while the beginner could keep up with his own share of obvious sounds.

The area where the Game is to be played needs to be taken into consideration. It could be played in any number of places unique to the Game's implementations. It could be as simple as a person in a room surrounded by speakers connected to an interface.

Figure 5 Speaker Setup[70]

[70] *Cheap Surround Sound*. Web. 28 Feb. 2011. <http://www.cheapsurroundsound.net/>.

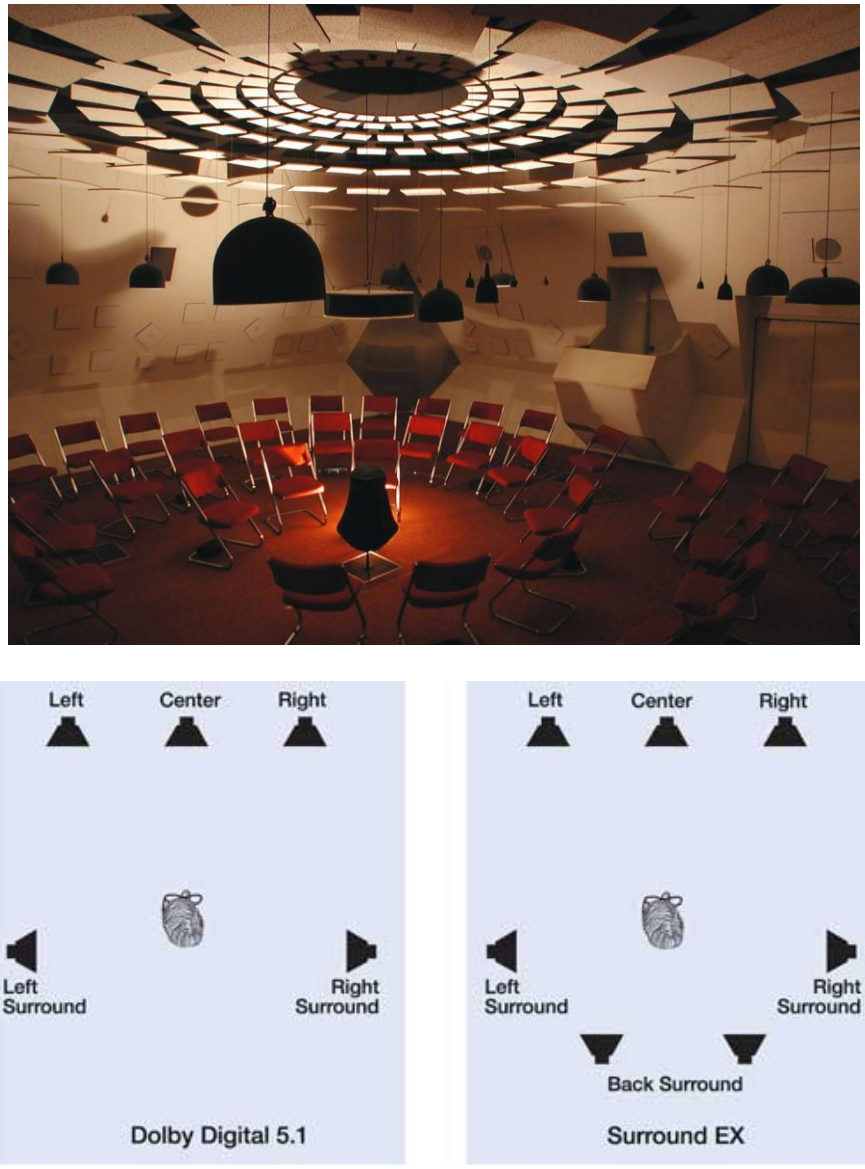

Figure 6 Surround Sound [71]

It can range to a concert hall with many audience members or potentially even wide open environments as shown in Figures 5 and 6. Playing the Game outdoors presents an entirely different experience. Neglecting any technological problems for the moment, imagine stepping out along a trail in the woods and hearing a multitude of birds and creatures. Not even just their

[71] "Media Rooms and Home Theaters." *Welcome to All Cape Audio Video*. Web. 25 February. <http://www.allcapeav.com/home_theater_andmedia_rooms.php>

sounds, but the wind, the leaves and trees swaying in the breeze, the sounds of crinkled leaves as squirrels and even you walk among them. Perhaps there would be a way to carry the controller (at this point, perhaps a cell phone or something even as simple as having a chip in your clothes), and one would be able to organize all of these random sounds into different places while they were constantly being emitted completely randomly because the source was "unknown" to the Game.

The Game would only be responsible for monitoring how the player was organizing the sounds from the woods, and measuring how intense the person was thinking. Perhaps the Game would have a monitor of the brain of the player, (for example, a futuristic transportable MRI) and one would be able to wear this transportable MRI (to be called tMRI from now on) as a hat or something simple that would not be a burden to either the person, the source of the sounds, or the Game's controllers. Then this person would be able to walk anywhere and be able to control sounds within the controller of the Game. The sounds would only be heard by that player, since the sounds would be kept within their own brain, (especially if they were very good at the Game and able to memorize an infinite amount of sounds and how they had already organized them previously). Even if the person were still a beginner, the Game would perhaps be able to monitor and play the sounds back for them if needed, but through the tMRI so the sounds would not actually be "played" but rather "injected" into the person's brain. Perhaps the tMRI would be able to work in this backwards way (rather than just monitoring the brain it would also be able to send signals to the brain) by injecting waves into the brain's waves and be able to create a signal that the brain would recognize as from the ears but it was actually from the waves of the machine's source instead.

3.3: Controller and Interface

When playing a game on any modern interface, such as the Xbox, Wii, Gamecube, etc., knowing the controller is half the battle. When you pick up the controller and you start a new game, you still know the basics of the controller; for example, when you begin a new first-person shooter game on the Xbox, you know that right-trigger is to shoot, the stick is to move and the left stick is to look around. You don't need this basic information because that is how most first-person shooters are designed.

This means that when thinking of the Game, it should have similar if not the same controller over all of the implementations; some sort of controller easily accessible to people everywhere, (such as being able to use your phone, Ipod, etc).

Not only should the controller be similar, but it should be something that the average person could control with ease. So it should not be as complex as a regular controller for any game system. Instead, to comprise of nothing more than a set of four arrows and perhaps a sensor so the person may physically move the controller and having done so have moved a sound from one speaker to another. This approach is similar to the recently developed Kinect system for Xbox 360. It allows users to use their bodies as the controllers and perform complex tasks without the need of a physical controller.

Figure 7 Kinect's Motion Sensitivity[72]

Another possibility would be to have a microphone on the controller, so the player may use this microphone to tell the Game what he or she wishes to do. There could be command words, much like in writing code, that would be registered within the computer of the Game (assuming a computer would be behind it all) and be able to control some aspect of the organization the player is trying to do.

However, as we move forward technologically, it would be ideal to be able to move away from any type of controller to simply using sensors. Much like the Xbox Kinect[73] system, the Game should be able to monitor the movements or even the thinking pattern of the player to move whatever sound or stimuli needs to be moved or manipulated. Here a futuristic MRI could be used, with its ability to monitor how the brain is working and functioning at any given moment. Utilizing this technology and the advancing technology of controller-less games, perhaps the Game will only consist of a sound-source and MRI. This way the Game would have both the stimuli required (the sound-source) and the ability to see what the person would want to

[72] "Kinect Release Date Announced at E3 2010 | Video Game Reviews, News, Tips, and Tricks - Video Game Reign." *Video Game Reviews, News, Tips and Tricks - Video Game Reign*. Web. 22 Feb. 2011. <http://videogamereign.com/xbox-360/xbox-360-news/microsoft-kinect-release-date-announced-at-e3-2010>.

[73] "Kinect - Xbox.com - Xbox.com." *Home - Xbox.com*. Web. 16 Feb. 2011. <http://www.xbox.com/en-US/kinect>.

do with that sound. The Game would be able to monitor the player naturally moving and manipulating it, (rather than having to learn a controller for it).

Chapter 4: Implementing Advanced Auditory Challenges

The entire purpose of the Game is to help aid in the development of cognition. Hesse's story provided forethought for the different types of challenges presented in this section. Essentially, the implementations are the most important portion of this project- to find places in the world that the Game may be used to assist people. This section is devoted to the implementations of the Game. The implementations will use existing methods of treatments for damages to the brain as well as theoretical research to create a basis for these implementations.

4.1: Auditory Problem Solving

Common to all games, problem solving involves the steps between realization of the problem and completing the goal. As an implementation of the Game it could serve both recreational and brain stimulating roles. The goal of this implementation will be to challenge every aspect that aids in problem solving, as outlined above. This can be done one of two ways: encompassing both experts and novice into one Game or creating different difficulties of the Game entirely.

In order to create the different levels of game play one would first have to investigate the background of different players. The first step would be to create a rating system by which expertise, memory, knowledge base, speed and efficiency, representation, appreciation of structural similarity, elaborating on initial state, and meta cognitive skills were able to be scanned for the player. This would most likely involve taking a pre-test for the Game. Based on how they did through the Game they would then be given a grade for further uses of this game.

The more challenging method would be creating a game that encompasses both experts and novice at the same time. This is closer to the overarching goal of the Game. In order to

accomplish this, the Game must be constantly reading information off the user. To accomplish this, a system would be in place using technologies outlined above, such as MRI and visual scanning. This information would be used to adjust the Game appropriately to the users' skill level. The challenge on behalf of the Game would be to adjust only enough to aid the user but still focus on brain stimulation and development.

In order to tie this into auditory stimulation, the Game will use auditory scene analysis (ASA). This process is how the brain organizes sound into perceptually meaningful elements.[74] [75]As described by Albert Bregman in his book entitled "Auditory Scene Analysis: The Perceptual Organization of Sound:

> "The best way to begin is to ask ourselves what perception is for....In using the word representations, we are implying the existence of a two-part system: one part forms the representations and another uses them to do such things as calculate appropriate plans and actions. The job of perception, then, is to take the sensory input and to derive a useful representation of reality from it."[76]

Bregman gives us a good example of what he proposes ASA to be. The brain's auditory system will assign location labels, within the brain, to bands of energies that come across it. These bands will go to their assigned spectral locations and the brain will identify the resolution with which it can do so.[77] This is what Bregman refers to as the primitive version of ASA.

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[74]34. Bregman, Albert S. *Auditory Scene Analysis: the Perceptual Organization of Sound*. Cambridge, Mass. [u.a.: MIT, 2006. Print.
[75]Brown, Guy J., and Martin Cooke. *Computational Auditory Scene Analysis*. Tech. Sheffield: Department of Computer Science, University of Sheffield, 1994. Print.
[76]Ibid.
[77]Ibid. pg 445.

Figure 8 Visual Diagram of ASA[78]

Figure 6 shows a visual version of the idea behind ASA. The first line is undistinguishable letter combinations. By separating certain letters two separate phrases are shown to exist. This is similar to the concept of ASA in which frequencies mixed together can be separated. The next level consists of selecting certain frequency components out of noise and hearing them as if they were the missing speech sounds. In particular, if one were to hear a mass of noise, the brain could hear something more due to a process in which the brain expects particular sounds to be there. This schema would be the representative of the sound pattern of a particular word. In an example:

> "...if we synthesize a two-formant speech sound in which each formant is constructed from harmonics related to a different fundamental frequency, listeners will have an unusual experience. They will hear two sounds, one corresponding to each related group of harmonics. Yet at the same time they will hear a single speech sound, the one conveyed by the full set of harmonics."[79]

This is where the problem solving idea of the Game comes in. In a room with 8 speakers, such as the one described in the Playing Field section, a mass of sound comes out of each speaker. The goal of the Game is to use this heightened version of ASA in order to figure out what sounds are being outputted. This can be akin to listening to your name being called out in a crowded room. Bregman describes this as a schema version of ASA in which through the multiple frequency of sound the user will be able to pinpoint different logical thoughts or ideas

[78] Bregman, Albert S. *Auditory Scene Analysis: the Perceptual Organization of Sound*. Cambridge, Mass. [u.a.: MIT, 2006. Print.
[79] Brown, Guy J., and Martin Cooke. *Computational Auditory Scene Analysis*. Tech. Sheffield: Department of Computer Science, University of Sheffield, 1994. Print. Pg 667.

expressed through the speakers. For example a John F. Kennedy's "Ich bin ein Berliner" speech could be played through a distorted mess of frequency. The next difficulty would be multiple ideas being played. In addition to JFK's speech, the speakers could be playing a truck's horn as the Doppler effect causes the truck to seem like its driving by the player. This would add various levels of ASA using both primitive and the schema-version analyzed by Bregman.

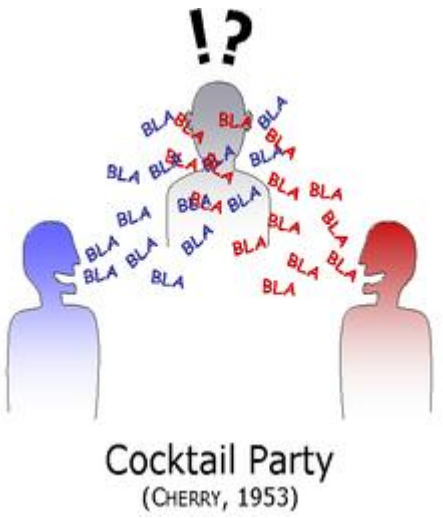

Figure 9 Perception and extraction of sound signals in context.[80]

This iteration will feature the "cocktail party effect," which simply is when one voice is intelligible when multiple voices are speaking. To expand upon this idea is that the brain is capable of distinguishing between multiple voices when presented in busy environment.[81]

Auditory scene analysis may have been what Hermann Hesse was referring to in his story as a means of dispersing information. The concept of ASA was unknown to Hesse, but it could be used explain some of the gaps in the details of his game. The game, as described in his story, has the entire world enveloped, making a direct exchange of information necessary. ASA theory

[80] "Neurosciences Sensorielles Comportement Cognition - Nicolas Grimault." *Equipes Du Centre De Recherche En Neurosciences De Lyon*. Web. 28 Feb. 2011. <http://olfac.univ-lyon1.fr/unite/equipe-02/grimault-e.html>.
[81] Bronkhorst, Adelbert. *The Cocktail Party Phenomenon: A Review of Research on Speech Intelligibilty in Multiple-Talker Conditions*. Rep. Soesterberg: TNO Human Factors Research Institute, 2000. Print.

will allow information to flow quicker when implemented in the Game, as described in this project.

The key to this project is in the distribution of information through multiple speakers outlined above. Having an assortment of speakers with multiple streams of information coming out is the idea behind ASA. To decide what set-up is most efficient will require a certain number of speakers. The process will have numerous speakers playing different sounds. Using ASA and the cocktail party concept the player of the Game will be able to coordinate the separate frequencies to a series and thus to information streams. The information will stream to the brain and then depending on the cognition of the player, will be sorted properly. This will allow for two things to happen. The first being the brain will strengthen and become used to this process. The next, and more important, is the amount of data the player will intake. The information gained will be delivered quicker than reading it ever could. The main idea is that player will have an increased ability to understand this information and it will be delivered more efficiently.

4.2: Biofeedback

Biofeedback is a technique that allows people to control certain bodily processes that normally happen involuntarily. The three methods of biofeedback include electromyography, thermal biofeedback, and electroencephalography. Electroencephalography, or neurofeedback, relates to measuring brain wave activity. Biofeedback as a therapy can be used to treat high blood pressure, tension headaches, migraines, or chronic pain. EEG Neurofeedback has been reported to improve the behavior and intelligence in children with attention deficit/hyperactivity disorder. Biofeedback is commonly associated with relaxation techniques or mental exercises to make therapy the most successful. [82]

Massimiliano Peretti conducted an artist-based project named the *Amigdalae Project* which was presented to the National Center of Scientific Research in Paris in 2005. Peretti used Biofeedback therapeutic methods to analyze people's emotional status while watching a video art piece. Actively responding to the biofeedback tests, the music they are listening to while watching the piece responds directly to the signals sent from the EEG. Doing this allowed Peretti to distort the emotion rendered from the video. This project was able to solidify the theory that perception and emotional reactions could effectively be modified to the whim of the user by using elements of sight and sound. If biofeedback could be implemented into the Game, users would theoretically be able to tap into the sounds required to modify emotional reaction and literally control emotion and perception. [83]

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[82]"Biofeedback." *University of Maryland Medical Center | Home*. Web. 15 Feb. 2011. <http://www.umm.edu/altmed/articles/biofeedback-000349.htm>.

[83]"Amigdalae." *World News*. Web. 15 Feb. 2011. <http://wn.com/Amigdalae>.

4.3: Audience Feedback

Another portion of biofeedback that must be considered is if there is an audience or not, and how the audience may interact with the player or players. In the case of having an audience, there would be some sort of feedback given from them as they watched the Game being played- however as the Game progressed the feedback from the audience would take longer and longer to get to the player. This would mean that initially, the player may choose to put a sound in one particular speaker, but the audience may disagree and so they might be able to vote on a small hand-held controller of their own and be able to tell the player nearly instantly of their mistake. However, as it continues the "super computer" behind it all may slow the response time of the audience, (by withholding their votes) and so when the player finally did get their responses, the player would have to remember what he or she did to get that kind of feedback.

An example of this in current television is the game "Who Wants to be a Millionaire" where the player has an audience and answers multiple choice question. The player has life-lines, one including an "ask the audience" option. Basically everyone in the audience has a hand-held device with four choices on it, (A, B, C, or D), and the audience may choose which answer they believe to be true. This is reflected in a simple bar-graph and shown to the player as soon as they have finished answering. This may affect the way the player answers, (for example if 90% of the audience believed D to be true, the player would probably choose D unless he absolutely knew otherwise to be true).

This could also add some challenge to the Game, as when people believe they know the answer to a problem they still doubt themselves when others tell them it is wrong, even when they are correct. There would be a fight within that one person whether to stick to their opinion or to go with the rest of the audience.

The Game could also provide feedback to try to dissuade the player from making a particular choice, or from taking a certain action. For example, a higher-level player may get feedback from the Game that tells them they are close to the optimal solution, but it may be incorrect feedback that the player must see through to see that they are actually missing a step or organizational piece. As described in *The Glass Bead Game*, the game paralleled the general evolution of cultural consciousness. The game is said to evolve multiple times throughout its history and the people using it evolved as well.

4.4: Memory Health

Today's treatments for miscellaneous head trauma depend on the damage done. For example, in mild amnesia the patient may only need a session with a therapist. In those sessions, the therapist attempts to dig through the patient's memories to find what caused the trauma, and be able to counsel them on how to appropriately proceed.[84]

Another form of treatment is hypnotherapy; when the patient (with the therapist's aide) relaxes into a focused, sleep-like state and is able to be taught how to respond differently to stimuli in their memories. This treatment is possible because of the fact that when a stimuli is realized by the brain, an emotion and other responses are attached to that stimuli. This is because the brain can learn, and so with stimuli it attaches a response so that the person may respond appropriately to those same stimuli later. However, it is possible for a person to respond to stimuli inappropriately due to miscellaneous defects or *mistakes* the brain can make. This is why someone could seek help from a hypnotherapist- the therapist goes through several stages to take

[84]*EzineArticles Submission - Submit Your Best Quality Original Articles For Massive Exposure, Ezine Publishers Get 25 Free Article Reprints*. Web. 17 Jan. 2011. <http://ezinearticles.com/>.

the memory apart and be able to eventually separate the stimuli from the response, and to replace that response with a more appropriate one.[85]

These treatments could be integrated into the Game, depending on how much one wanted to use it for a treatment rather than just a game to improve their memory capabilities. For example, in hospitals the Game could be designed to lull the patient into a sleep-like, extremely focused state before beginning the actual Game. The patient could be placed in a completely blacked-out room with speakers in one of the predetermined setups outlined in Chapter 3. As the speakers emit sounds the patient must try to remember where the different tones were and how they could relate to one another. As the patient got better, the Game could increase in difficulty in that either more speakers were added, or simply the speakers emitted more sounds on top of one another and so on. To help treat a specific patient, whatever issue the person may have may be associated with a certain sound, (for example if the person were in a vehicle accident the sound of the crunching of the cars is often involved) and so that sound would be broken up and played in different ways until that person could respond differently to that stimuli.

4.5: Emergent Behavior with Multiple Players

The idea strategized in this implementation is to allow for multiple people to work together to achieve a common goal. The Games' challenges rise to a different level when they are presented to a group of people. Differences in organizational strategies, general knowledge base of the Game, and keenness in auditory stimulation play important factors that, as a group, must be dealt with in order to get through the goal. A group-play option is important in the idea that players can pay attention to one another, realizing their patterns or independent strategies in a means that is more effective than if someone was an audience to the other. Playing alongside

[85]"Hypnotherapy." *University of Maryland Medical Center*. Web. 17 Jan. 2011. <http://www.umm.edu/altmed/articles/hypnotherapy-000353.htm>.

another person teaches potential problem solving methods that they alone may not have come to realize.

The difficulty in this section lies in the fact that controlling an emergent behavior system is very hard to conceptualize. "The concept of emergence, in itself, offers neither guidance on how to construct such a system nor insight into why it would work."[86] How is one to accomplish this goal of creating a system where the idea that something greater will come out of it? One can start by looking at smaller examples of emergent behavior.

Group games can take place in homes, between families or friends, or potentially even in public spaces. There is definitely a potential for the Game to take place in a stressful environment such as an airport to help relax travelers. Airports provide a specifically unique dynamic for the Game. This comes from the congregation of the Game's potential users. Game enthusiasts, or people who haven't seen the processes of the Game, have the ability to play alongside each other, novice and professional alike. These people are nearly 100% unique to each other. Coming from different areas of the world, which just happen to be at the same airport at the same time, with completely unique aspirations, histories, and personalities given the chance to learn from one another.

People find a certain novelty in working together. Similarly to laser-tag, players are often paired or teamed up with complete strangers to achieve a specific goal. Once players are immersed together in this "game environment," the brain is allowed to focus for the good of achieving the goal personally, as well as for the good of the team. Even to complete strangers, people are found to have a drive to set up positive impressions to show their personal worth for

[86]Hillis, Danny. "Intelligence as an Emergent Behavior Or, The Songs of Eden - The Long Now."*Front Page - The Long Now*. 16 Feb. 2010. Web. 21 Feb. 2011. <http://longnow.org/essays/intelligence-emergent-behavior-or-songs-eden/>.

the good of the Game.[87] People are found to try harder in environments where they are challenged such that they are deemed useful and a critical proponent to the Game as perceived by the other players.

An example of emergent behavior is when a video- game programmer commands that in a racing game, the cars are not allowed to crash. The algorithm is only specific to keep the vehicles from crashing into one another, but this slows the cars that were near an accident state and so that causes the cars behind the original ones to slow. That happens to the cars behind those cars and so on until the game has a traffic jam, which is something the programmer had not intended. Emergent behavior basically brings about by-products of the final product- be they bad or good they come along with the final product without having been planned. That is why it is so difficult to create the actual Game that we are proposing- because we have to try to keep room for events or by-products that we are not planning, and that are impossible to plan (since that is the definition of emergent behavior).

A video game called "Heroes of Telara" is going to be released soon and part of its advanced game play is that it is based all around emergent behavior. In other words, players from all over the world may come together to work on different missions, and by-products may emerge from their individual goals. As stated by the game producers, the game can be constantly changed by player and maker alike. The outcome is unforeseeable even by the video-game makers, much like how the traffic jam was unforeseen by the racing game programmer. "There are small events, there are big events, there is even emergent behavior in the game that changes the game world. A lot of it is not even known to us, it's like the ghost in the machine. The game

[87] "Challenge and Motivation." Challenge and Motivation. Web. 10 Feb. 2011. <http://education.calumet.purdue.edu/vockell/edPsybook/Edpsy5/Edpsy5_challenge.htm>.

is almost alive, and that allows you to create heroes."[88] The difference between this type of game utilizing emergent behavior and the type of activity we are proposing it that the video-game's emergent behavior is "structured," with a "rule set." For example, they state that the world of the game will be changed due to the decisions the players make. However, these decisions are prompted from very certain and planned questions for the players, and so the emergent behavior is dependent on something that is very structured and very certain.

Meanwhile, the activity we are proposing requires that there is no "structure," there is no "rule set." So the emergent behavior is dependent on nothing that is structured or controlled. As stated above, all problems consist of three parts; the original state, the goal state, and the rules.[89] However, what would happen if we took away one of these parts, or instead gave the power over to the player to control them? For example, what if the person performing the activity were to be given all power over the goal, and over the rules to attain the goal that they set? Then the Game would have no control over the structure, and so the emergent behavior would be completely and utterly new. It would not depend on anything that the Game designers did, or what they thought.

In this way, emergent behavior can form in an even greater aspect; rather than having a by-product of the solution; it could create an entirely new and "bigger" solution. Of course one can only speculate on what that might be (since that is the definition of emergent behavior), but what if something developed that was so over-encompassing that it became a new basis of intelligence?

Hesse says early in *The Glass Bead Game*, "The players, mutually elaborating these processes, threw these abstract formulas at one another, displaying the sequences and

[88]"Trion: Telara MMO Will Feature 'Emergent Behavior'" Web.
[89]Matlin, Margaret W. *Cognition*. Fort Worth: Harcourt Brace, 1994. Print.

possibilities of their science."[90] The people playing the game combined the limits of their knowledge and somehow processes formed. This is essentially the idea of emergent behavior, to have the possibility for something to emerge. The game basically evolved by just being played. It had grown from a simple game using glass beads to a complex network of information.

[90] Hesse, Hermann, Richard Winston, and Clara Winston. *The Glass Bead Game: (Magister Ludi)*. New York: Picador USA, 2002. Print. Pg. 31 to 33

Chapter 5: Conclusion

The goal of this project was to design the foundation of a modern version of the game described in Hermann Hesse's *The Glass Bead Game.* Research was conducted to investigate the feasibility in Hesse's ideas and whether or not an activity could be designed as a model of them. While this project does not attempt to quantify cognition, the Game may have the potential to provide a positive, new means of human learning. Consideration was given into the design of the physical implementation of the Game. Finally, the challenges in the Game are designed to specifically target the brain and are rooted in the evolutionary history of humans.

The concept of emergent behavior provides a greater potential outside of the primary design of the Game. Since the project does not delve into the specifics of the Game, it remains unknown as to exactly how humans would respond to it. There are logical arguments based on the research that would encourage a physical implementation of the Game. This project was based around *The Glass Bead Game*, using the background described by Hesse. His game promotes cognitive development through processes never completely defined. This project furthers the idea originally developed by Hesse, and can be used by future projects.

This research creates questions to be answered by projects in the field of psychology, evolution, and sound. What is the best way to create a situation where emergent behavior is possible? Where will the state of the art of technology be in the future to support the physical implementation of the Game? How will auditory scene analysis be utilized to create the actual auditory problems? How will advancements in medical fields affect our abilities to monitor brainwaves? *The Glass Bead Game* could realistically be implemented once answers to these questions are found.

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